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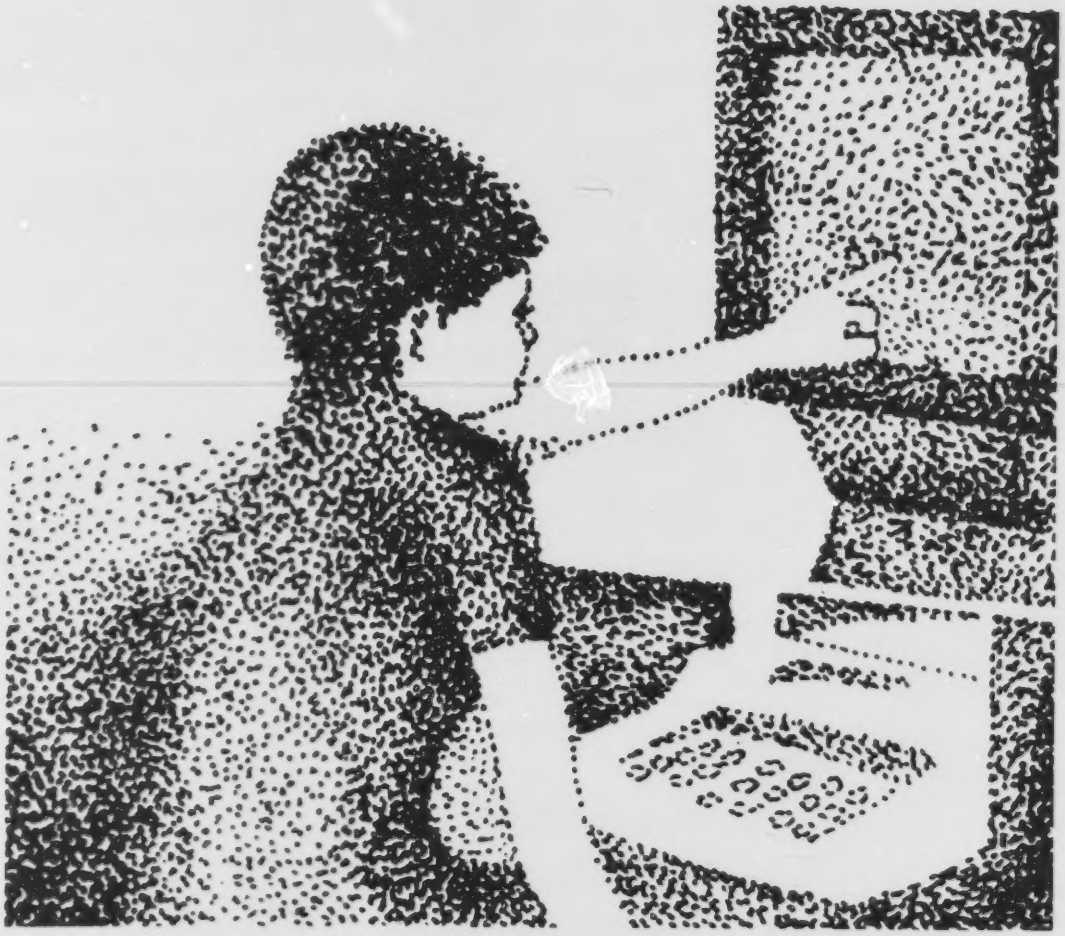
ABSTRACT

Expenses related to the instructional use of computers in education are reviewed in depth. These expenses can be in seven different areas; terminals, computer, telecommunications, software, courseware, operation, and human resources. A cost breakdown is given for the different instructional uses classified in volume 1 and for different educational systems and computers. Costs are given on a per pupil basis for a year and for a terminal hour. Summaries and comparisons of costs are provided in appendixes. (WH)

ED 092087

Report on The Instructional Use of the Computer

Volume II
Costs



Service de l'Informatique
Ministère de l'Education
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Canada

IR 000 645

ED 092087

Report on

THE INSTRUCTIONAL USE OF THE COMPUTER

Volume II

Costs:

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Laboratoire de Pédagogie Informatique
Service de l'Informatique
Ministère de l'Éducation du Québec
March 1973

The instructional use of the computer

Volume II

COSTS

The three volumes* of the document "The Instructional Use of the Computer" are the result of a report submitted to the Department of Education in March 1973 by the Laboratoire de Pédagogie Informatique. This study, directed by Mr. William Lee, continues the work done by the Laboratory set up in 1968 within the Department of Education's Data Processing Service.

In the first volume the classification and description of the types of instructional uses to which the computer may be put are the work of Guy Chevalier and the experiment reports, the work of Bernard Gateau.

The second volume on the costs of the various computer uses was written by François Labrousse.

The third volume which describes the scope of computer use in education is the work of Lucien Dubé.

The final copy was put together and given its finishing touches with the assistance of Miss Diane Laflamme and Mrs. Céline Brochu.

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*Volume 1: "Types of uses"
Volume 2: "Costs"
Volume 3: "Scope"

CLASSIFICATION OF THE INSTRUCTIONAL USES OF THE COMPUTER *

AS A LABORATORY TOOL

- ELECTRONIC EQUIPMENT
- CALCULATOR
- AUTOMATON
- SIMULATOR
- RESEARCH AND DEVELOPMENT TOOL

AS AN INSTRUCTIONAL MANAGEMENT TOOL

- INFORMATION BANK
- TESTING AID
  - ANSWER PROCESSING
  - TEST GENERATION
  - INDIVIDUALIZED TESTING
- COMPUTER-MANAGED INSTRUCTION

AS A TEACHING INSTRUMENT

- DRILL AND PRACTICE
- TUTORIAL
- DIALOGUE

** Cf Volume I of this report: "Types of Uses"*

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INTRODUCTION

The computer does not have a reputation for being an inexpensive tool. In the educational world, where the problem of costs is especially important, its use depends to a great extent on the expenses entailed as compared with the quality of instruction provided.

Justification of a computer in industry or administration is not necessarily a decrease in costs, but more probably a new development or a step forward which the computer fosters or makes possible; a similar phenomenon can be expected in education. Some even claim that the computer needs no more justification than the telephone or libraries which are obviously considered indispensable (24).

In any case there exist very few operational economic data on the instructional use of the computer. Experiment reports are generally from the research field. Costs should be assessed rather on the basis of a fairly extensive use.

The various expenditure items will be discussed in the first chapter, after which the cost of each type of instructional use of the computer* will be assessed.

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* The classification used is that given in Volume I of this report.

CHAPTER I

COST ANALYSIS

1.0 Classification

Expenses entailed or modified when a computer is used for education may be classified under various headings:

1- Terminals
2- Computer
3- Telecommunications
4- Software
5- Courseware
6- Operation
7- Human resources

They will be studied in succession, and a brief description as well as a scale of costs will be given*.

1.1 Terminals.

When the computer is used for remote processing, terminals or consoles are brought into play. Telephone lines are used for telecommunications.

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*The use of a product exclusively for educational services (telecommunications, computer equipment) generally involves special rates.

Terminal capacity varies greatly with the type used. This may be anything from a simple teletype to a small computer.

There will be no discussion here of "remote batch" terminals (punched card readers, printers) which are essentially an extension of the computer room hardware, but which can be used for teaching data processing *(automaton)* or for *instructional management* (information bank, for example).

Rather our discussion will be concerned with "conversational" terminals, generally used by only one student at a time, allowing him to communicate actively with the computer (29, 8): typewriter-like terminals (teletype, IBM 2741, for example), miniprinters, and keyboard and CRT display terminals.

1.1.1 *Typewriter-like* terminals

The purchase price of these terminals varies from about $1,000 to some $5,000 depending on their potential.

One of the most common and least expensive is the Teletype which includes various models, the prices* of which are given in the table below (price before the educational discount):

MODEL NUMBER	manual terminal	automatic terminal
33	$ 55	$ 70
35	$105	$140

Fig. 1 - *Monthly costs of Teletype terminals.*

To transmit or receive messages over telephone lines, a device (modulator-demodulator: modem) must be placed between the terminal and the line at each end. This device is incorporated with the Teletypes mentioned above. It should be noted, however, that for other terminals - GE - 300, for example, with a monthly rent between $145 and $235 - this device must be added. For communication with the computer, the cost of such a modem

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* Prices quoted by Bell Telephone Company.

is $17.50* a month.

As a result the average annual cost of renting a fairly simple terminal of this type would be about $1,000.

1.1.2 Cathode ray tube terminals

There are many models of this type of terminal. Few of these have been designed for educational purposes (like Lektromedia, LATO). Their possibilities are highly variable and costs are even more so. The use of display terminals for instructional purposes requires screens with a certain flexibility bringing the purchase price to between some $3,000 and $6,000, that is a rental of about $100 per month.

Let us consider Project PLATO's plasma display panel**.This terminal makes a superimpression of a projected image possible (4). At the present time it costs $4,000 (12); the estimate for 1974 is $2,500 and it is hoped that it will finally drop to only $1,900.

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* Prices quoted by Bell Telephone Company.

** According to *CAI/CMI Information Exchange News*, January 1973, published by Entelek, about one hundred of these terminals have now been completed. They are assembled by Magnavox Co.

1.1.3 Other terminals

Other terminals can be used for teaching at the same time as a conversational terminal. Thus, a slide projector or a tape recorder can be added to the student station, the whole controlled by the program. The IBM 1500 system offers these possibilities. This is a system specially developed around an IBM 1130 for computer-assisted instruction.

The Bell Telephone Company now offers a cathode ray tube (very simple, without instruction-oriented specialization) at $70/month and a modem at $17.50/month, a mini-printer ($95/month) and a cassette reader ($90/month, 50,000 character capacity).

Let us also note that units such as punched card readers or marksensors* may be very useful in combination with a typewriter-like terminal or mini-printer.

1.2 Computer

1.2.1 General

The use and cost of the computer vary a great deal depending on the method used to integrate it into the educational system.

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* Such a punched card reader or marksensor, is sold for $12,000 (market price: without the educational discount); rental approximately $250 a month. It reads 120 cards a minute.

Discussion here will be concerned in particular with a computer operating on shared time used in the conversational mode.

The cost per terminal decreases when the system is a larger one serving a greater number of terminals. However, if terminals are scattered within an installation centered on a powerful computer, telecommunication costs cancelling this advantage might be involved.

It can be worthwhile using a commercial time sharing service especially when only a few terminals are required. Often, an estimate of costs then involves the following three factors:

- calculating time of the central unit ("CPU" time)
- terminal-computer connection time;
- volume occupied by auxiliary storage.

The hourly rate for a commercial time sharing service is about \$10 $\pm$ \$4, since telecommunications generally have to be added.

One method for estimating costs which will allow a comparison of such very different solutions is to calculate the price of one hour's work at a terminal or else of one month's or one year's work. For this purpose, an "average" connection of six to ten hours a day is assumed.

1.2.2 Cost of systems designed for education

a) The estimated cost for the 1970-71 year of an RCA Spectra 70 serving 192 terminals in New York (33) was $190,000. It does not seem possible that the cost of the terminals could be included in this price although the text is ambiguous on this point. The cost of a computer would then be about *$1,000 per terminal per annum.*

b) In Kentucky, the EKEDC's* EMRI project (Educational Management Research Information System) served 3,800 pupils at 62 terminals in the spring of 1972 (12). The terminals in question were ASR 33 teletypes connected with an RCA 70, and the *cost of a terminal per annum was $960.* The terminal itself cost $950.

c) As a guide, the costs given by Kopstein and Seidel in 1967 for the hardware of three different installations can be quoted (18).

These costs include expenditures for the computer and terminals (but not for telecommunications) in three types of use:

- 6 hr/day, 22 days/mo;
  132 hours per terminal per month;
- 10 hr/day, + 5 hr. Saturday;
  240 hours per terminal per month;
- 18hr/day, + 9hr. Saturday;
  432 hours per terminal per month.

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* EKEDC: Eastern Kentucky Educational Development Corporation.

i) For an IBM 1460 and 20 pupil stations:

TYPE OF STATION	HOURLY COST PER TERMINAL			MONTHLY COST OF INSTALLATION
	Used 132 hr./mo.	Used 240 hr./mo.	Used 432 hr./mo.	
Simple Terminal	$5.30	$2.95	$1.74	$14,000
Terminal with Projector	$7.65	$4.25	$2.46	$20,200
Complete Station with Audio	$7.85	$4.35	$2.52	$20,700

Fig. 2 - *Monthly cost of IBM 1460 installation + 20 stations, and hourly cost calculated per pupil (Kopstein and Seidel, 1967)*

ii) For an IBM 1500 with 32 complete stations (screen, projector and audio):

	HOURLY COST PER TERMINAL			MONTHLY COST OF INSTALLATION
	Used 132 hr./mo.	Used 240 hr./mo.	Used 432 hr./mo.	
Complete Station	$3.63	$2.04	$1.20	$14,800

Fig. 3 - *Monthly cost of IBM 1500 installation + 32 stations, and hourly cost calculated per pupil (Kopstein and Seidel, 1967)*

iii) For a hypothetical installation, with 448 stations and a PDP-10 (amortized over 48 months)*:

TYPE OF STATION	HOURLY COST PER TERMINAL			MONTHLY COST OF INSTALLATION
	Used 132 hr./mo.	Used 240 hr./mo.	Used 432 hr./mo.	
Teletype	$0.50	$0.28	$0.16	$28,800
Cathode ray tube and keyboard	$0.93	$0.51	$0.29	$54,300

Fig. 4 - *Monthly cost of PDP-10 installation + 448 stations, and hourly cost calculated per pupil (Kopstein and Seidel, 1967)*

---

* This hypothesis seems highly advantageous and involves rather low costs.

1.2.3 Cost of commercial time-sharing.

a) In February 1973, costs* for the Dartmouth time-sharing service were as follows:

TYPE OF RATE	CONNECTION TIME (depending on speed)			CALCULATING TIME	STORAGE SPACE	INPUT/ OUTPUT
	10 char. /sec.	13.45 char. /sec.	30 char. /sec.	per second of CPU time	per 4000 char. unit	per 1000 I/Ø units
INSIDE	$1.40	$1.55	$2.30	$0.04	$0.35	$0.55
NON-COM-MERCIAL	$2.15	$2.35	$3.55	$0.06	$0.65	$1.00
COMMER-CIAL	$5.25	$5.80	$8.65	$0.15	$2.00	$2.50

Fig. 5 - *Rates of the Dartmouth Time-Sharing System services, February 1973*

* Obtained from the DTSS (Dartmouth Time-Sharing System). A more complete table is given in Appendix D.

These unit prices, although representative of market rates, may seem rather high. Moreover DISS (Dartmouth Time-Sharing System) offers annual contracts at a much lower average hourly rate ($6,000 for 4896 hours of availability).

b) In 1971, Seltzer gave the following costs for the Michigan Terminal System at the University of Michigan (28):

Terminal connection	$2.57/hr.
Calculating time (CPU)	$286/hr. (8¢/sec.)
Memory space	$0.37/hr., per page
Storage space	$0.28/hr., per 1000 pages

Without using the storage file, an hour of work at the terminal in this case thus comes to about $4 - $4.50/hr. for use of the computer.

c) In January 1973, the cost of the APL system available at the Université Laval for outside clients was:

Terminal connection	$3/hr.
Calculating time	$0.15/sec.
Storage space	$0.80/track-month

A track allows storage of 13,030 bytes.

d) Suggested commercial rates for a time-sharing service are thus markedly higher than the calculated costs for educational installations. However, estimates do not always take into consideration the technical support personnel.

Of course it is only natural that there should be differences in cost since the services offered are different.

1.2.4 PLATO

In the PLATO IV project (3, 4), Bitzer assesses a high powered system built around a computer* capable of serving some 4000 terminals. The yearly costs for a terminal (2000 hours: 45 weeks, 44 hours a week) would amount to:

computer	$220
software	$ 25
system management	$ 60
	$305

Bitzer adds the cost of the terminal itself ($360 to $1000) to this figure, which is particulary low and subject to dispute (29).

1.2.5 Cost of a small system.

As an example of a small system we can mention the system offered by Computer Curriculum Corporation (described in (33) in 1970). This is a small computer serving eight terminals and designed for a course in elementary arithmetic (Suppes' *drill and practice* course). The system is somewhat restricted but independent and relatively inexpensive. Other courses could be offered with a slightly more expensive system. Total annual cost for com-

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* In (12), it is specified that the 4000 terminals could be supported by four CDC 6400 or two CDC 6500.

puter, terminals and maintenance is estimated at $7,640, or about $350 for the use of a terminal for one year.

1.2.6 Changes in costs

The appearance of large systems, or even of mini-systems designed especially for the field of education, has resulted in considerable decreases in costs as compared with former systems (29, 32) born of a less highly-developed technology and developed for research purposes. We think this trend should continue.

1.2.7 Conclusion

The figures we have given show wide discrepancies which may be explained by the different uses (a lighter or heavier load per terminal) and the varying degrees of profitability (more or less powerful systems, night time use of the computer, and so on).

At the present time, the annual cost which can be charged to the computer alone (without the terminal) in an installation designed for educational purposes should not exceed about $3000 per pupil station. A lower limit might be estimated at $1000. An operational - as opposed to a research - system should lean towards the lower figure.

1.3 Telecommunications.

In an installation connecting a computer with scattered or remote terminals, the telecommunication costs may become considerable and act as a decisive factor.

One of the main advantages of small independent installations with only a few terminals, is that costs for this item may be nil.

1.3.1 Ordinary lines

Conversational terminals, taken separately, can use ordinary telephone lines. A regular call may be made if it is very short and sent a slight distance outside the local calling zone; but costs quickly become prohibitive.

Rental of a line can then rapidly become economically interesting: the average cost is a few dollars a mile. In the United States, Bitzer (4) gives an average cost of $3.50/mile per month. In Québec*, the average monthly rate is about $4/mile, but varies with the areas served. On the Government network, the monthly rental is considerably lower: the per mile cost varies with the number of circuits. As a guide, here are the prices for rental of an ordinary line (2,400 bauds) Québec - Montréal on one hand, and Québec - Chicoutimi on the other. Costs for regular rental and for the Government Telpak network are both given.

---

* Data supplied by the Bell Telephone Company.
See alsc (1).

	Monthly cost for regular network	Monthly cost for Telpak network
Québec-Montréal	$521	$194
Québec - Chicoutimi	$472	$309

Fig. 6 - *Monthly costs for rental* of ordinary telephone lines, 2,400 bauds.*

The diagram for use would be as follows:**

Fig. 7 - *Diagram of terminal and computer connected by telephone line*

and the cost of such a connection as follows (Telpak network):

	Monthly cost of telephone line	Monthly cost of modems	Total monthly cost of hook-up
Québec-Montréal	$194	$35	$229
Québec-Chicoutimi	$309	$35	$344

Fig. 8 - *Examples of monthly telecommunication costs for computer-terminal connection using a rented line.*

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* Supplied by Bell Telephone Company (figures rounded off to the nearest unit)

** The device called a "modem" was explained previously (p.4).

When there are several terminals in the same location, the possibility of concentrating telecommunications so as to reduce costs can be considered.

Accordingly, an ordinary line of the duplex type, specially conditioned, can transmit messages from eighteen "slow" terminals (15 characters/sec.).

The following table gives the increase in cost for this quality of line, as compared with the foregoing:

	Monthly cost for normal network	Monthly cost for Telpak network
Québec - Montréal	$721	$305
Québec - Chicoutimi	$660	$425

Fig. 9 - *Monthly costs* for rental of conditioned duplex lines.*

The diagram for use would be as follows:

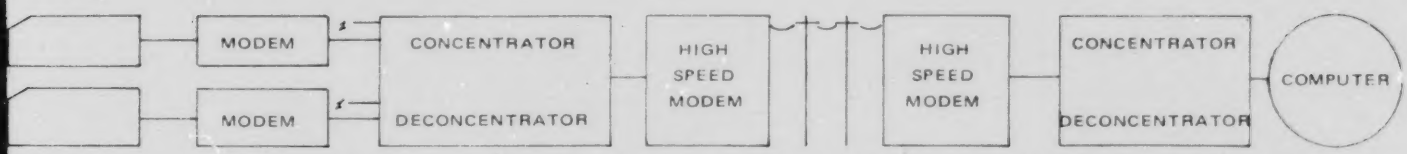

Fig. 10 - *Diagram of terminals connected to a computer with concentrated lines*

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* Data supplied by Bell Telephone Company (rounded off to the nearest unit).

At each end of the line, a line concentrator-deconcentrator and a high speed modem is required. Moreover, each terminal must have its own modem connecting it with the concentrator as well as a device (electronic circuit card) enabling it to work in this mode.

As many as twenty-five terminals on the same 2400-baud line, mean the following monthly costs* for this apparatus:

- cost for each terminal $ 12.50
- modem " $ 17.50
- concentrator-deconcentrator $242.50 (each)
- high-speed modem $115.00 (each)

Total cost of connection to the Telpak network on the two lines under consideration would be as follows, in terms of the number of terminals:

NUMBER OF TERMINALS	QUEBEC-MONTREAL LINE		QUEBEC-CHICOUTIMI LINE	
	Total cost	Cost per Terminal	Total cost	Cost per Terminal
5	$1,170	$234.00	$1,290	$258.00
10	$1,320	$132.00	$1,440	$144.00
15	$1,470	$ 98.00	$1,590	$106.00
20	$1,620	$ 81.00	$1,740	$ 87.00
25	$1,770	$ 70.80	$1,890	$ 75.60

Fig. 11 - *Example of monthly costs (total cost and cost per terminal) of telecommunications with line concentration on rented lines.*

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* Supplied by Bell Telephone Company.

In these two examples, line concentration becomes advantageous rather quickly: from five terminals on the Québec-Montréal line and three terminals on the Québec-Chicoutimi line.

1.3.3 Television cable

If we look to the future, we can visualize systems with great numbers of terminals served by a television channel. Such a system does not yet exist in Québec, but is being studied. Bitzer (4) proposes the following system:

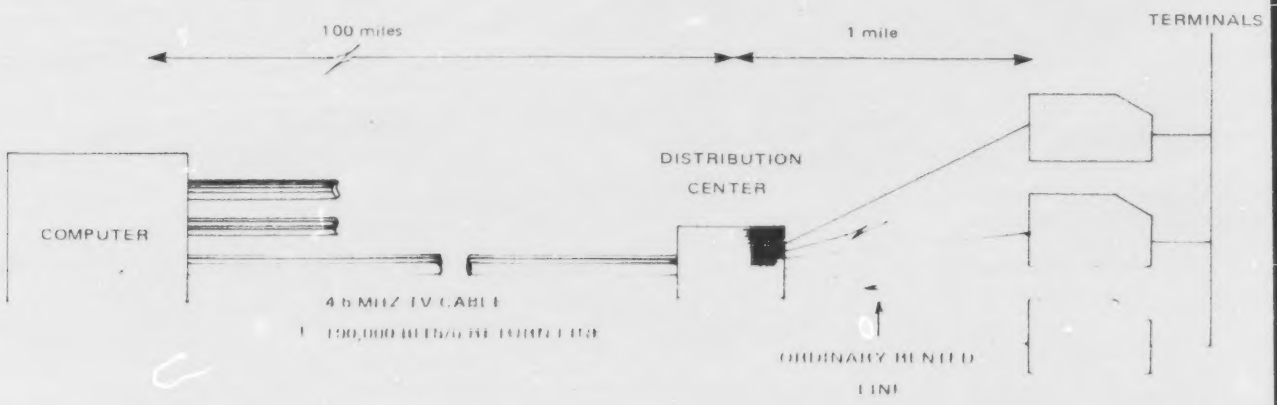

Fig. 12 - *Diagram of a system using T. V. Cables (Bitzer, 1971)*

The television channel could transfer 1200 bits/sec. to each of the 1500 terminals. The return line could transmit the answer from each of the 1500 terminals at 60 bits/sec.

Hence the table on the next page.

	MONTHLY COST PER MILE	TOTAL MONTHLY COST
TV Channel	$35	$3,500
100,000 baud line	$15*	$1,500
TOTAL	$50	$5,000

Fig. 13 - *Estimate of telecommunications cost for 1500 terminals as proposed in the foregoing diagram (Fig. 12) by Bitzer, 1971.*

The result, per terminal is $3.33/month plus the cost of the terminal line ($3), that is, $6.33 per month.

For 160 hours' monthly use, the result is the amazingly low figure of 4¢/hour per terminal for telecommunications.

1.4 Software

Here we are not referring to the courses themselves, which will be studied later, but rather the systems for programming them: course programming will, in fact, be included in the output.

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* This cost seems rather low, compared with about $25/mile for a 50K bits line in Québec. Modems would also have to be taken into consideration.

1.4.1 Types of software

Several types of software can be involved - the computer's operational system (OS), a non-specialized conversational language adapted to computer-assisted instruction (for instance, APL or BASIC), or even a specialized system developed specifically for this purpose (Coursewriter, and LYRIC for example). The cost of the first type can be considered part of the computer operation, as it would be if a time-sharing service were rented.

1.4.2 Conversational languages

The cost of renting a conversational language, or rather, its compiler or interpreter, depends on the machine which is to receive it, its power, complexity, technical support personnel, and so forth. The approximate cost would be several hundred dollars per month.

1.4.3 Education-oriented languages

a) In 1970, Silvern (29) furnished the following costs for rental of the LYRIC System, created specifically for education; these costs depend on the number of terminals using the system:

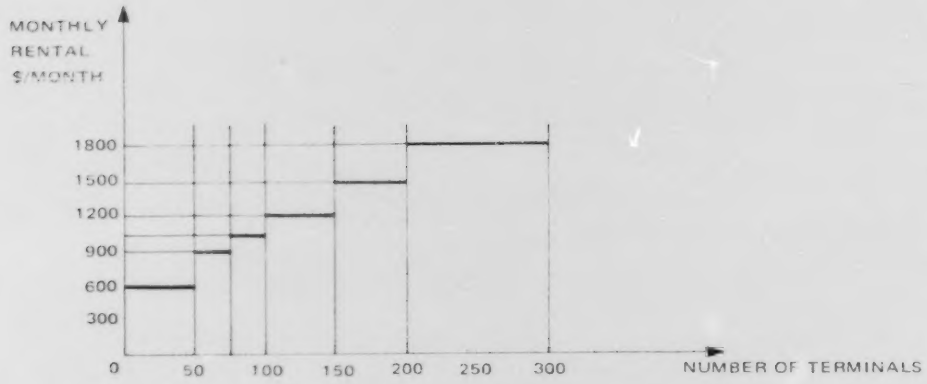

Fig. 14 Monthly cost of the LYRIC system (Silvern, 1970)

b) Kopstein and Seidel (18) assume that development of a specialized language requires twenty man-years and costs $360,000. Amortized over a three-year period in ten centers, the cost is $1,000 per month. In the three cases of use below:

- 2,640 hr/month: 20 students x 6 hrs. x 22 days
- 7,680 hr/month: 32 students x 10 hrs. x 24 days
- 193,536 hr/month: 448 students x 18 hrs. x 24 days

the amortization cost per pupil-hour is $0.38, $0.13, $0.005 respectively, and per month for each terminal: $50.00, $31.20 and $2.23.

c) In the PLATO program, Bitzer (3) estimates the amortization cost of the language at $25 per terminal per annum, the cost of course writing ($500,000) then being spread over the 4000 planned terminals, with a five-year amortization period.

1.4.4 Estimate of the cost for software

The cost of conversational software applicable to instruction, when not included in the cost of the computer, would probably amount to between $3 and $15 per month per terminal.

For example, a "package" renting for about $300/month, in an installation serving 30 terminals, would come to about $10/month per terminal. Use for 5 hr/day and 24 days/month would entail an hourly cost of $0.083.

1.5 Courseware

Writing a course in which the computer plays a certain role is a lengthy operation and the final touches are important. It may be compared with writing a manual or preparing audio-visual material. The figures quoted by the writers pertain more to *tutorial* courses than to *computer-managed instruction*. It may be estimated that for an equal period of study by the pupil, it will take at least twice as long to write a tutorial course than a CMI program.

In any case, cost is directly related to quality, to the extent that quality improves with the care given, and therefore with the time taken to write the course. The cost of tutorial courses, generally calculated in terms of one hour for an average pupil, may vary in proportion between 1 and 15: $200 to $3,000.

1.5.1 Costs for use as a *teaching instrument*.

The following table gives a few figures concerning use of the computer as a *teaching instrument*.

ACCORDING TO	PREPARATION TIME PER HOUR OF INSTRUCTION	COST PER HOUR OF INSTRUCTION
- Stolurow (32)	100-400 hrs.	$1,200 to $4,800
- Sharp and Wye quoted by (29)	234 hrs.	$1,170
- Atkinson, Suppes quoted by (19)		$ 450
- Bacon, quoted by (19)		$ 500 to $3,000

Fig. 15 - *Time and costs quoted for writing up one hour of a course using the computer as a teaching instrument.*

$1,500 can be considered the amount a trained, specialized, team would cost at the present time for writing, revising and validating one hour of *tutorial* instruction. Costs can be as little as one half or even a third of this for *drill and practice* (see above reference to Suppes).

1.5.2 *Computer-managed instruction* **costs**

For *computer-managed instruction* the cost of writing a course could be estimated at between $500 and $1,000 per pupil study hour. However, the difference can actually be very great depending on the work required for preparing accompanying material.

1.5.3 Commercialized courses.

There are commercialized courses, particularly of the type *drill and practice*. They are intended for elementary subjects such as reading or arithmetic. The pupil spends an average of 10 minutes a day at the terminal. The cost of renting these courses (according to (12))is about $100 a year per terminal. If we consider that every day 25 to 30 pupils may use the terminal, the annual cost per pupil and for each course offered is from $3 to $4.

1.6 Operation

Some operating expenditures involved in computer-assisted instruction are comparable to those of traditional instruction (manuals, printed material, audio tapes, slides or films), while others are related to computer operations (punched cards, printing paper, and the like).

These expenses are marginal but cannot be ignored. In *computer-managed instruction*, the pupil often works on printed or audio-visual material which he keeps or which must be replaced rather frequently. In the *tutorial* mode, terminals such as photo projectors or tape recorders also involve costs for renewal of material. (cf. (4) and (9)).

Moreover there are some administrative costs such as the services of a secretary that some authors bring in by adding a percentage to the total costs, for example. Generally speaking, we shall include these costs in the sector under which they come.

1.7 Human resources.

The cost of the teaching personnel (teachers, supervisors, instructors) involved when the course is distributed is the main item under this heading. The costs for other personnel such as operator, programmer, analyst, secretary... are included under the heading described above.

The computer is a tool in the educator's hands, freeing him from routine tasks (correction and drill and practice) and thus making him more often available. Because of that, costs may be modified;

- the teacher with more free time, can handle a greater number of pupils;
- the role of the instructor, in some types of use, can be entrusted to persons with lower qualifications (graduating students, student or inexperienced teachers).

As the student progresses from the elementary to the university level, he develops greater ability to work on his own: he is more and more proficient in organizing his work; in individualized instruction, and, in particular, in computerized instruction, the need for a teacher's presence decreases; thus, the teacher/pupil ratio also decreases. Moreover, the use of the computer at the university level, as stated by W. Dick and P. Gallagher (9), seems to reduce the teacher's load. On the elementary level, however, it seems that such a gain can not yet be hoped for (cf. Project PLAN).

1.8 Summary of the present cost of education

An appreciation of the costs arising from the instructional uses of the computer cannot be made without reference to the present cost of education in Québec.

The table below gives the overall costs for the elementary, secondary and college levels. They are in dollars per pupil per year. The amount and percentage for the teaching personnel are also included.

EDUCATIONAL LEVEL	OVERALL COST PER PUPIL	COST OF TEACHING PERSONNEL	
		cost	percentage
Elementary 71-72 (21)	$570.	$263.	46%
Secondary 71-72 (21)	$1,052.	$530.	50%
College 70-71 (20)	$1,397.	$706.	50%

Fig. 16 - *Present cost of education in dollars per pupil per year.*

On all three levels, the cost of teaching personnel accounts for approximately half the total cost.

In comparison, college-level education in the United States is estimated (11) at $667, of which about 57.4 percent is for actual instruction.

If the total cost given in the table above is divided by the number of hours pupils are in class, on the different levels, a total hourly cost per pupil is obtained, which can become an interesting basis for comparison:

EDUCATIONAL LEVEL	NUMBER OF HOURS OF INSTRUCTION PER ANNUM	HOURLY COST PER PUPIL
Elementary	900 hours	$ 0.63
Secondary	975 hours	$ 1.08
College	891 hours*	$ 1.57

17- *Number of hours of instruction per annum and hourly cost per pupil for the first three educational levels. (22,23).*

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* This figure is approximate and based on the following data:

- two regular 82-day sessions, that is 164 days or about 33 weeks.
- In general education, courses involve about 25 hours per week, and in vocational education, about 29 hours per week. An average of 27 hours per week for 33 weeks has been used.

To be more specific, the following are the expenditures recorded on the three levels for items where educational technology plays a major role. These expenses could be influenced by the use of the computer.

	TEACHING MATERIAL		LIBRARY AUDIO VISUAL		LABORATORY		DATA PROCESSING	
	ANNUAL COST	% OF TOTAL COST	ANNUAL COST	% OF TOTAL COST	ANNUAL COST	% OF TOTAL COST	ANNUAL COST	% OF TOTAL COST
ELEMENTARY	$12.37	2.17	$ 7.05	1.24	- -	- -	- -	- -
SECONDARY	$19.28	1.84	$22.42	2.13	$23.09*	2.20	- -	- -
COLLEGE	- -	- -	$81.45	5.8	$72.50	5.2	$34.90	2.5

Fig. 18 - *Cost and pro rata percentage of total cost of technological items in $/pupil-year (20,21).*

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* Regular and vocational laboratories.

CHAPTER 2

ESTIMATE OF COSTS FOR USE AS A *LABORATORY TOOL*

2.1 Use of the computer as *electronic equipment*

In this case the computer or some simplified equipment is used for studying decision elements, wiring and the like. Such a tool must be classed among apparatus for electric, electronic and physics laboratories and so on, and the choice must depend on the same criteria as used for similar tools, measuring apparatus or experimental apparatus.

In an extreme case, the cost may actually be nil (outdated equipment given by certain companies for training technicians).

This type of use modifies neither the methods nor the organization of the instruction given.

2.2 Use of the computer as a *calculator*

Two types of use can be distinguished in this category:

- conversational use of the computer;
- use of independent calculators or minicomputers.

2.2.1 Conversational mode

a) Description

The computer is required to carry out certain calculations; the pupil uses a high-level language or one of its sub-sets. One console can be used by several students in succession. The code is frequently short and the results required are limited (console or mini-printer output). Calculating time depends on the complexity of the program, which can very greatly. Machine time (CPU time) is very slight as compared to the connection time: the manual input of data and the printing of results (where applicable) is slow. The ratio: CPU time/connection time varies from 1/50 to 1/1000 according to the power of the machine and the type of program submitted.

b) Examples

According to Hickey (15), in February 1968, the Dartmouth Time-Sharing Service, catering principally to educational institutions, yielded an average calculation/connection ratio of 1/144 for sessions averaging 16 minutes.

At the present time, the ITF system at SIMEQ has a ratio of about 1/960*.

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* The high speed of the SIMEQ computer goes a long way in explaining this rather low figure.

2.2.1 ...

The reader has been given the costs for time-sharing systems, and in particular for the DTSS service. In this system, for a one-hour session entailing 20 seconds CPU time, without file storage, the following computer cost is obtained:

connection:	$5.25
CPU time :	$3.00
total :	$8.25

In comparison, similar costs (excluding terminal and telecommunications costs) for the ITF system at SIMEQ can be estimated at $1.80/hr. However it should be noted that the ITF is not as powerful as the DTSS and offers fewer possibilities.

c) Estimate of costs for the conversational mode.

For this type of use the cost covers mainly the computer, the terminal and perhaps telecommunications. The costs for software may in this case be considered as included in the computer costs.

The following figures for an hour of use are indicative:

computer :	$1.50 to $6.00
terminal rental :	$1.00 to $3.00
	$2.50 to $9.00
+ telecommunications:	$0.00 to $3.00
total :	$2.50 to $12.00 per hour.

2.2.2 Calculators or minicomputers.

With this type of equipment the computer's power is lost, but the flexibility of an independent tool is gained without telecommunication costs or complications.

The purchase of such apparatus involves between $3,000 and $15,000. Amortized over five years this would mean $600 to $3,000 per annum. Used for 800 hr/yr. the *hourly cost would be between $0.75 and $3.75.*

2.3 Use of the computer as an *automaton*

In this type of computer use, the students write programs and put them into the computer (scientific calculations, data processing instruction).

The computer may be local or remote. In the first case it may be small or medium-sized, and its work as an automaton represents only part of its task. In the second case, it may be used:

- for conversational mode: manual introduction of programs by the pupil; output on the terminal or miniprinter;
- for remote batch processing. Requirements: card or tape punching, remote batch terminal.

Here again, it is difficult to give an average cost, since the variation in prices may be enormous, even for two programs of comparable length.

For the conversational mode, the rates given for the *calculator* are still valid*. Use as an *automaton* may lead to more extensive compilations (longer CPU time) and the storage of longer programs in the libraries.

Conversational use allows data to be introduced directly into the terminal, thus avoiding punching costs. On the other hand, the system's flexibility encourages more numerous exchanges between student and computer. This increases the work load and, consequently, the cost.

To have a general idea, it could be estimated that the cost of introducing a program ranges from less than one dollar to several dollars.

2.4 Use of the computer as a *simulator*

Two types of simulation programs can be distinguished:

i) programs in the conversational mode.

Using the terminal the pupil furnishes data or parameters to the program which returns the simulation results. The pupil's work with the simulation is in real time.

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* Paragraph 2.2.1: total cost between $2.50 and $12.00/hr.

ii) batch or remote batch programs.

Data are supplied on punched cards or tapes, and the results come out in deferred time on the printer or plotter...

In each of these cases, there is no basic difference between a simulation program and a traditional data processing program.

The costs vary greatly. They may be negligeable or reach some $50 or so for each use of the program. For the same work, a batch processing program will, generally speaking, be less expensive than a program in the conversational mode.

As a general rule, introduction of simulation into a *tutorial* course or *computer-managed instruction* will entail greater costs; but real experiments which are even more costly or actually impracticable in a small laboratory can thus be replaced. The increase is due to two factors:

- writing simulation software is similar to writing scientific calculation programs. It is lengthy painstaking work;
- generally speaking a simulation program requires more work by the computer than part of a *tutorial* course, for example.

2.5 Use of the computer as a *research and development tool*

We will not give any estimate here of the costs involved in the use of the computer as a *research and development tool*, since such costs are too variable.

The work is often conventional - for instance, the statistical processing of results - and entails the usual costs for business data-processing.

Experiments on the instructional use of the computer may also be involved, as for example, the comparison of two methods of presenting information or of analyzing students' answers. In this case the cost of the course presentation will correspond with the cost of the mode in question (cost of the computer, the terminal, telecommunications...). On the other hand the cost of writing an experimental course will be amortized over a small number of users only. It is therefore natural to consider the overall cost of the experiment rather than a per pupil or per hour cost, which in this case has no meaning.

CHAPTER 3

ESTIMATE OF COSTS FOR USE AS AN *INSTRUCTIONAL MANAGEMENT TOOL*

3.1 Use of the computer as an *information bank.*

3.1.1 Presentation

The use of the computer as an information bank is not peculiar to the educational field. Of course, the use made of the processed data does not affect the costs and sorting out instructional objectives or book titles would require the same amount, to the extent that the computer's work would not change.

The references available mostly concern information banks for educational documentation, especially books.

3.1.2 Estimates of costs

It is difficult to be precise when dealing with costs in this use. A distinction must be made between *batch processing*, *remote batch processing* and *conversational*. This last mode is being put to increasingly greater use. It requires, for every inquiry station, a terminal, which may be very simple (teletype or cathode ray tube), and possibly, the use of telecommunications.

The computer cost is mainly the result of the need to keep the system available all day long (central unit attendants) and manage vast files (large volumes in auxiliary storage).

The annual cost per inquiry station in a conversational system used all year can as a result be roughly estimated at between $1,500 and $5,000, operating and personnel costs excluded.

3.2 Use of the computer for *testing*

Here we have to distinguish between two types of computer testing which are quite different from the data processing point of view. One takes place in *real time* with conversational terminals and the other in *batch processing* with collection of the results, card punching, for instance, and batch processing.

Generally speaking, calculations are rather limited in number in both cases, unless elaborate statistical processes are involved. The cost of data processing will be estimated below. The amortization of the cost of preparing questionnaires and testing programs must accordingly be added to these costs.

3.2.1 Batch processing

The correction program used in SIMEQ on an IBM/370-165 for secondary level examinations may be given as an example.

In 1972 this program made it possible to process some 2,300,000 examination papers, 1,220,000 of which were objective tests. The program corrected these and compiled the results of the others. The following operations were necessary:

	cost per sheet
- Purchase of answer sheets (one questionnaire per sheet) $17,875 for 2,750,000 sheets.	$0.0065
- Preprinting of sheets: 600 hr. of printing, with CPU time	$0.0012
- Automatic reading of sheets: 7 visual scanners for three months	$0.0091
- Operation of visual scanners: an average of 1 person per reading	$0.0032
- Analysis and writing of correction and validation programs: 15 days for analysis, 6 weeks for writing and testing.	$0.0006
- Execution of program:	
validation: 800 CPU seconds for 120,000 sheets	$0.0027
correction: 15 CPU minutes for 1,220,000 sheets	$0.0003
total	$0.0236

LPI Report, 1973, vol. II

To obtain the overall cost of computer processing, it would be necessary to add such other items as analysis and programming for preprinting, and data processing administration and management, which would bring this partial total to some 3¢ per corrected answer sheet.

Moreover, considerable expenses for handling (receiving, sorting, shipping) or manual intervention had to be assured. Estimated in this case at between $160,000 and $180,000 they bring the total cost for correction to 10 or 11¢ per answer sheet.

This example seems representative of a fairly large automatic correction system. It can be observed that in this case the actual cost of computer runs was rather low: handling accounted for about 2/3 of the expenses.

For this type of use we will adopt the approximate average cost of 10 to 15¢ for the automatic correction of a questionnaire of about 50 items. This does not include the cost of writing the tests.

3.2.2 Real time processing

The computer's work during the test is comparable in this case to that of a *teaching instrument*. The terminal is used both to ask the pupil questions and receive his answers.

The length of a test varies from one pupil to another and the time spent at the terminal can give an idea of the cost.

As will be seen in the section on the *teaching instrument**, a test requiring an average of 30 minutes at the terminal will entail about $1.00 to $3.00.

3.3 Use of the computer for *computer-managed instruction*

3.3.1 Example one (not conversational): Project PLAN.

a) Description

One of the most elaborate examples of *computer-managed instruction* is Westinghouse Learning Corporation's system, PLAN.

In the initial approach, the system operates in the United States, on a central computer (IBM 370-155, at the present time) to which the schools are connected. The computer is located in Iowa City.

Generally, the school has a terminal capable of reading manually marked cards ("mark-sensing", 12 cards/minute) and a typewriter-like console which acts as a printer.

Terminals are connected with the computer by 4800-baud lines. There are 33 at the most and they are scattered throughout the United States. The total number of pupils involved in 1970 was about 30,000 in 79 schools (35).

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* cf. Chapter 4.

Every day, the pupil fills out a card indicating his progress in the subject unit he is studying. At least once per unit he answers test questions, again on a card. The student takes about three weeks to complete a unit.

The whole set of cards is read and processed at night: this requires four hours of processing*. Reports are sent to the schools during the night.

The processing is relatively simple, since no records are kept of the pupils' results (for statistical purposes, for example); it is merely noted that they have completed the unit.

b) Cost**

i) Installation would require $50 per pupil for the first year.

To cover the cost of:

- equipment (computer and terminal)
- telecommunications,
- programs,
- instructional material,

Westinghouse charges $100 per pupil per year.

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* The program occupies 200K in storage.

** We have no breakdown of the costs shown.

ii) Another source of information makes it possible to give more specific figures for a PLAN client (about 500 pupils) during the 1971-72 school year (180 days).

- operating costs.

Each terminal costs $825/month, telecommunications included. On this basis the monthly cost for two terminals comes to $3.30 per pupil.

Operating costs, then, are:

terminal-telecommunications	$ 3.30
computer	$ 2.80
course, teaching material	$ 6.00
	$12.10

that is, for nine months, $108.90/pupil.

- installation costs:

total cost	: $5000
cost per pupil	: $ 5

which brings the per pupil cost to $15.

It should be noted that the training of personnel must be added to the installation costs:

$500 for ten days administrative training,
$300 for 5 days training per teacher.

iii) *For project PLAN, then, operating expenses of about $110/pupil for one year may be assumed.*

It must be noted that these costs are additional: the organization of courses is obviously different; the teachers are not assigned to classes as in traditional instruction; however, generally speaking the number of teachers remains about the same.

This is true for the system under consideration, at the present time involving the elementary level, for every subject, and every grade. However, for an older student body, the need for teaching personnel should not be as great, since the pupil's autonomy could increase.

c) Development

Westinghouse is reorganizing its system, so that the schools no longer depend on a central computer. This seems quite natural in view of the telecommunication costs and the rapid saturation of the computer. In this case local computers of modest size are used, (2000 HP), serving a limited number of terminals, about ten, for instance.

The card reader used will be quicker (400 cards/minute as compared with 12 for the model mentioned above); its purchase price will be $10,000, its rental, about $2,000 a year.

The cost of $100/per pupil per year will already be dated and it is to be expected that the new approach and an extension of the system would bring about a considerable drop in cost.

3.3.2 Analysis of the costs of *computer-managed instruction* (not conversational)

a) Computer cost

A small computer designed to serve ten terminals and about 3000 pupils in this mode could come to about $35,000 rent per annum ($3,000 a month).

Expenditures for operations and personnel attached to the computer increase this price by about 50 percent.

Such a computer would certainly not be saturated in this case and could be put to profitable use providing other services. The sum of $35,000 per annum may serve to give an idea of the cost price of the computer, operating expenses included.

b) Costs for terminals

The PLAN price of $825/month for each terminal seems high. This is perhaps due to the cost of telecommunications which must be considerable in the system adopted (centralized). The terminals themselves, card reader and typewriter-like models, must involve a rental of about $450/month, or $5,400/year.

A decentralized installation should reduce, if not eliminate, the cost of telecommunications which will not be discussed here.

c) Total cost for equipment

If we consider that one terminal serves 300 pupils (that is 3000 pupils for the computer), the following are the costs per annum:

computer	:	$ 3,000
terminals	:	$ 5,400
Total	:	$ 8,400
that is, per pupil-year	:	$ 28

d) Total cost per pupil

Let us add to the above costs:

- rental of courseware : $54/year*
- instructional material: $ 9/year (PLAN figure)

the total comes to $91 per pupil per annum.

A total estimate of *$90 to $100 per pupil per annum* seems realistic and corresponds to existing figures.

3.3.3 Example two (conversational) at the university level

At the other end of the academic scale, an experiment in *instructional management* was conducted at Florida State University (9).

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* The figure quoted by PLAN is $6/month. Wide circulation of courseware would be likely to reduce this amount, which accounts for almost half the total cost.

The course, for one semester and three credits, was given to 59 students. Here is a summary of the detailed estimate of costs:

a) Development costs:		
CMI course development	$ 1,400	
CAI coding and feeding course into computer	$ 7,817	
clerical work	$ 80	
Total	$ 9,297	$ 9,297
b) Operating costs:		
- documentation		
books	$ 264	
reproduction	$ 80	
Total	$ 344	
- instruction		
publication of the guide	$ 150	
assistants (students)	$ 1,760	
teacher (1/10 of the time)	$ 450	
Total	$ 2,360	
- computer	$ 865	
total operating costs	$ 3,569	$ 3,569
Total cost of project:	$12,866	$12,866

The writers conclude by declaring that the operating cost for this course represents half or even a third of the cost for the corresponding traditional course.

The following are remarks concerning these figures:

- The course is for university students. Within the present educational context, it is actually quite expensive.

- If we calculate an amortization over three years for the university course (the subject was techniques of programmed learning), the figure reached is $3,100/year. For 60 students per semester, or 120 a year, the cost would be $26 per student.

  Since operating costs are about $60/pupil, the total would come to $86/pupil for three credits (45 hours of instruction).

- The average time spent at the terminal was 4.4hr per student. The ratio of on-line time to the total time is thus about 1/10, which is normal.

  It should be noted that in this case the pupils are in direct interaction with the computer, a contrast with Project PLAN mentioned above.

3.3.4 Analysis of the costs for *computer-managed instruction* (conversational)

Computer-managed instruction, used in the conversational mode, is similar to the *teaching instrument* used for *drill and practice*; the pupil regularly goes to the terminal to report his progress to the program and receive tests or recommendations.

In paragraph 4.1.3 it will be seen that for 10 minutes of daily interaction with the courseware, the computer - terminal cost per pupil may be estimated at $56/year.

The courseware will cost the same or slightly more than in the preceding case; here a cost of $55 will be assumed. Thus we reach the figure:

computer-terminals (including software)	:	$56
courseware	:	$55
instructional material	:	$10

That is, a total of $121, telecommunications excluded. In this case, we can quote the total figure of $130 to $140/year per pupil.

CHAPTER 4

ESTIMATE OF COSTS FOR USE AS A *TEACHING INSTRUMENT*

4.0 Introduction

This is the type of instructional use of the computer on which the greatest number of articles and books have been written.

This information shows no concensus on estimates and even in cases of relatively similar uses one cost given may double or triple another.

The discrepancy becomes appreciable when the costs of systems in the planning or development stages are introduced, especially if the project promoters have their say.

The costs of the most optimistic planned systems and the present usual costs are in a 1 to 10 ratio. ($0.35/hr to $3.50/hr).

The three types of computer use in the *teaching instrument* category are arranged in order of increasing instructional elaboration. Costs grow at the same rate since pupil-computer interaction time increases, as well as degree of difficulty and length of course preparation time.

Using data in the first chapter, we shall estimate the cost of a few typical applications of the computer in this mode. Then, taking a hypothetical example, we shall add the telecommunication costs of setting up a system.

4.1 Use of data processing equipment

4.1.1 The terminal

When the computer is used as a *teaching instrument*, the pupil's session at the terminal generally lasts from ten to thirty minutes. Because of the close attention required of the pupils and to allow a satisfactory flow of pupils to the terminal, non-experimental sessions rarely last longer. It can be assumed that during one hour, between two and six pupils will take a turn at the terminal.

If we assume that the terminal operates eight hours a day, it will be used by a maximum of 40 pupils, or, for a five-day week, 200 pupils. For our calculations, we shall work with an actual rate of use of 6 hours per day. Taking delays into consideration, as well as the interval between pupils, real connection time will be longer, 7 to 8 hours, for example.

Then suppose that the pupil is to work at the terminal every day. This gives the number of pupils one terminal can serve, depending on the rate of turnover:

- two pupils an hour : 12 pupils per terminal
- six pupils an hour : 36 pupils per terminal.

It can be considered that six pupils an hour is quite a suitable rate for *drill and practice*. A rate of two pupils an hour is better suited to *tutorial* instruction or *dialogue*

4.1.2 The computer

There does not seem to be much difference in the load imposed on the computer between the three types of *teaching instrument* applications: *drill and practice* requires less machine time, but there are more student answers than in the *tutorial* mode or *dialogue*.

4.1.3 Cost: computer and terminal (including software)

This makes it possible to estimate the cost of equipment for the three applications (*drill and practice*, *tutorial* and *dialogue*), that is the computer and programs on the one hand, and on the other, the terminals.

a) According to the figures quoted in paragraph 1.2.7, the cost of a computer for the school year, the support program included, can be taken at $1000 per terminal.

b) For the terminal, a cost of $1,000 can be considered. (cf paragraph 1.1)

c) We obtain a yearly total of $2,000. At the rate of 6 hours a day and 20 days a month (1,080 hr/yr) we come to an hourly cost of $1.85/hour per pupil.

d) Per pupil per annum, we obtain the following costs for computer and terminals (including software):

2 pupils/hour : $ 167 per pupil

6 pupils/hour : $ 56 per pupil

4.2 Course-writing (cf paragraph 1.5)

4.2.1 Pupil population

The number of pupils who will use the course must be known to calculate the amortization:

- the number of pupils per annum
- the number of years a course is used.

It may be supposed that a high quality course will be used for several years. However, it will have to be changed and improved on the basis of many parameters: pupil reaction, teacher reaction, program changes. If these improvements are not made,

the course will gradually be abandoned in favor of another; if they are, the maintenance costs will come into play and compensate for the gain in not writing another. A *five-year* amortization period might be suggested, as for equipment, in order to obtain an approximate cost.

Three different course distribution possibilities may be considered for calculation purposes: 100 pupils/year, 1,000 pupils/year and 10,000 pupils/year. That is, for five years: 500, 5,000 and 50,000 pupils.

4.2.2 Writing time

We shall assess course writing time independently of distribution. These two variables are in fact certainly interdependent, but this would be very difficult to account for.

For the three types of use under consideration (*drill and practice*, *tutorial* and *dialogue*), the difference in writing time is noticeable. For *drill and practice*, many examples can easily be created from a single exercise pattern: two numbers to add, a verb to conjugate in a certain tense, and the like. In the *tutorial* mode, this advantage largely disappears. For in *dialogue*, the courseware takes still longer to prepare than for *tutorial* instruction.

4.2.3 Cost of courseware.

According to the figures quoted in paragraph 1.5.1 the following costs can be used:

- for *drill and practice* : $500 per course hour;
- for *tutorial* instruction: $1,500 per course hour.

Let us recall the figures for the use of the computer per student (180 days per annum):

- for 10 minutes a day:
  1,800 minutes = 30 hours of courses
- for 30 minutes a day:
  5,400 minutes = 90 hours of courses.

Hence the following costs for courses to be taken during a school year:

- for *drill and practice* : $ 15,000
- for *tutorial* instruction: $135,000

With a five-year amortization, the annual cost comes to $3,000 for a *drill and practice* course and $27,000 for a *tutorial* course.

Per pupil, per annum, the course cost is then as follows:

TYPE OF COURSEWARE	ANNUAL COST OF COURSE	COST PER PUPIL ACC. TO DISTRIBUTION		
		100 PUPILS/ YEAR	1,000 PUPILS/ YEAR	10,000 PUPILS/ YEAR
Drill and practice	$ 3000	$ 30	$ 3.00	$ 0.30
Tutorial	$27000	$270	$27.00	$ 2.70

Fig. 19: *Cost of amortization of courseware.*

4.3 Total cost.

4.3.1 Limited hypotheses

Supposing that:

- the cost of telecommunications is nil because of the proximity of the computer (pupils of the same city with a computer in that city, for example),
- the number of teachers is the same as for traditional instruction,

the annual cost for each pupil with reference to course distribution can be obtained. This cost is shown in the table on the next page.

TYPE OF COURSE-WARE	ANNUAL AND HOURLY COST PER PUPIL ACCORDING TO COURSE DISTRIBUTION					
	100 PUPILS/YEAR		1,000 PUPILS/YEAR		10,000 PUPILS/YEAR	
	per annum	per hour	per annum	per hour	per annum	per hour
drill and practice (10 min./ day per pupil)	$ 86	$2.87	$ 59	$1.97	$ 56	$1.87
tutorial (30 min./ day per pupil)	$437	$4.85	$194	$2.16	$170	$1.89

Fig. 20. *Cost for each pupil for a course in which the computer is a teaching instrument (including: terminals, computer, programs, courses and operation), per annum and per hour.*

4.3.2 Estimate of costs for setting up a system.

For an estimate taking telecommunications into account, a special case must be considered. Suppose that in Québec, an installation serves elementary pupils in three cities: Québec, Montréal and Chicoutimi*. This is advantageous from the viewpoint of telecommunications since the cities are already linked by the Telpak telephone network.

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* A more extensive installation would certainly not be considered in this way.

Suppose we wish to serve:

in Montréal	:	1,300 pupils
in Québec	:	500 pupils
in Chicoutimi	:	200 pupils
total	:	2,000 pupils

and offer six different *drill and practice* courses (one per grade). Every day 36 pupils would use the same terminal.

a) Number of terminals required:

in Montréal	:	37
in Québec	:	14
in Chicoutimi	:	6
total	:	57

that is, a total annual cost of $57,000 for terminals ($1,000 per terminal).

b) Computer and support programs:

$57,000 per year ($1,000 per terminal).

c) Telecommunications:

As we saw in the first chapter (paragraph 1.3.2) line concentrators could be used.

i) Thus between Québec and Montréal two 2400-baud* lines would serve the purpose, one feeding 18 terminals and the other, 19:

1st line (18 terminals) : $1,560/month

2nd line (19 terminals) : $1,590/month

ii) Between Québec and Chicoutimi, one line would be enough:

6 terminals : $1,320/month.

iii) For in Québec itself, only the modems will be counted on the assumption that the government network would be used:

For 14 terminals : $ 490/month (28 modems).

The monthly total would come to: $4,960.

To calculate the annual cost, only nine months rental need be considered for the school year - that is $44,640/year.

d) Courses: six different courses, of 30 hours a year, for 2,000 pupils (five-year amortization) will each cost $500 per course hour.

Total cost	:	$90,000
Total annual cost	:	$18,000
annual cost per pupil	:	$ 12

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* It would actually be possible to use a single 4800-baud line. However, we shall retain this approach which seems more representative of use based on a network.

e) Hence a total cost per annum of:

- terminals	:	$ 57,000
- computer and software	:	$ 57,000
- telecommunications	:	$ 44,640
- courseware	:	$ 18,000
total	:	$176,640

or a cost per pupil of : $88.32/year

$ 2.95/hour at the terminal.

f) These figures call for certain remarks:

- This is an example of an estimate for the initial introduction of a system, and not for a system open to all elementary school pupils.
- A low rate of use has been estimated for the terminals since their rental is amortized only over the six hours of use described (real operation time is 7 or 8 hours).
- An identical comment should be made on the cost of renting lines. However only nine months' rental has been counted, a hypothesis which would have to be re-examined in a real system.
- The overall cost of the six courses represents $90,000 for 180 hours.
- The improvement in the teaching staff's work load could be considerable: in Montréal, for instance, 37 terminals distributed among several schools would allow a re-examination of school organization; and even if not reflected in a decreasing number of teachers, the improvement should show up in the quality of instruction and the progress made by the pupils.

4.3.3 Conclusion.

The figures quoted in 4.3.2, as well as the various estimates quoted by the author (when they are not the result of a report on an actual experiment) or made by ourselves, have been obtained through hypotheses and approximations; they must be regarded in this light.

To secure a more accurate estimate, it would be necessary to define clearly the conditions of computer use within the context of the project which must go beyond the experimental or semi-experimental stage.

We could then hope to lower the cost for the example quoted in 4.3.2. Were a greater number of pupils involved, it would be possible to consider several choices in setting up the teleprocessing network. In particular a satellite network would lead to savings in computer-telecommunication costs.

Such a system would depend on a series of medium-sized or minicomputers linked by fast lines with a central computer. Depending on the distribution of the terminals and the type of use, the role of the satellite computers would vary from simple line concentration to responsibility for most of the processing. In the latter case, the central computer would be primarily a vast data bank.

The cost of the terminal does not seem likely to show any spectacular decrease. Rather it may be hoped that for the cost of today's simplest terminal we will obtain ever-increasing pos-

sibilities.

Finally, reductions in the cost of course amortization can be hoped for as distribution grows.

Conceivably, improvements along these lines will make the computer an indispensable tool in the educational field.

APPENDICES

A- As a conclusion to this volume, a table summarizing the estimates given here of the costs for the various types of instructional uses of the computer.

It must be remembered that this is an estimate of *average* costs of greater interest than extreme cases, which are often unreliable.

B- A table summarizing the costs, given by the various authors, for the use of the computer as a *teaching instrument*. Note the great range.

C- A note providing additional information on an important experiment quoted in Appendix B.

D- A copy of the rates for the Dartmouth Time-Sharing System (DTSS).

SUMMARY

APPROXIMATE AVERAGE COSTS FOR INSTRUCTIONAL USE OF THE COMPUTER

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a : Terminals

b : Computer

c : Telecommunications

d : Software

e : Courseware

f : Operation

g : Human resources

CLASSIFICATION	items counted	items not counted	items not involved	COSTS AND COMMENTS
1. LABORATORY TOOL				
1.1 Electronic apparatus			*a,c,d,e*	variable depending on apparatus
1.2 Calculator				
- computer conversational	*a,b,c,d,f*	*g*	*e*	$2.50 to $12.00 per hour of use
- calculators and minicomputers	*b,d,f*	*g*	*a,c,e*	$0.75 to $3.75 per hour of use
1.3 Automaton	*a,b,c,d,f*	*g*	*e*	from less than a dollar to several dollars per program run
1.4 Simulator				highly variable
1.5 Research and development tool				highly variable

CLASSIFICATION	items counted	items not counted	items not involved	COSTS AND COMMENTS
2. INSTRUCTIONAL MANAGEMENT TOOL				
2.1 Information banks	a,b,c,d,	f,g	e	$1,500 to $5,000 per annum, per inquiry station
2.2 Testing - batch processing	b,d,f,g	c	a,e	10¢ to 15¢ per questionnaire
- processing in conversational mode	a,b,c,d,f	e,g		$2 to $6 per hour
2.3 Computer-managed instruction	a,b,c,d,e,f	g		$90 to $140 per annum per pupil
3. TEACHING INSTRUMENT*				
3.1 Drill and practice	a,b,d,e,f	c,g		$1.80 to $3/hour per pupil $55 to $90/year per pupil
3.2 Tutorial	a,b,d,e,f	c,g		$1.80 to $5/hour per pupil
3.3 Dialogue				$170 to $450/year per pupil

* Telecommunications are not included in the costs given here; for an example including these costs, see paragraph 4.3.2

APPENDIX B

COST OF THE COMPUTER AS A TEACHING INSTRUMENT

(figures quoted)

In parentheses: partial cost
In brackets: cost estimated on basis other then pupil - hour

Year	Author	Cost	Comments
1965	E.N. Adams "The Computer Physics Instruction" 1965, quoted by (14) and (7)	$3 - $5 / pupil - hour	IBM 1500
1967	Kopstein and Seidel (18)	$2.61 / pupil - hour	IBM 1500, 32 stations 10h/day, 24 days/month breakdown: hardware $2.04 software+courses $0.52 administration + supervision $0.05
1968	Carter, Walker (Booz Allen-Hamilton), quoted by (31)	$2.27 / pupil-hour $2.53 / pupil-hour	Drill and practice, 10,000 students tutorial, 10,000 students
1968	Committee for Economic Development, quoted in (7)	$1.15 - $3.08 / pupil-hour	Cost to be added to that of traditional education Calculated for 6h/day, 150 days/year
1968	Stolurow (32)	[($7.40 / pupil-hour) $2,225 / terminal-month] [$1.95 / pupil-hour $585.15 / terminal-month]	Estimated for IBM 1401 IBM 1500 system, 32 terminals $18,725/month, 300hr/month; estimate of cost-computer and terminal only

Year	Author	Cost	Comments
1968	Zinn, quoted by (19)	$2 - $15/pupil-hour	
1969	Robert A. Seltzer (28) University of Michigan	($2.57)/pupil-hour	Terminal time only; add: computer, program, course, administration . . .
1969	Atkinson, Suppes, quoted by (19)	$1.80/pupil-hour	Everything included *
1970	Keith Hall (14)	$3.00/pupil-hour	Reference to E.M. Adams (1965)
1971	Kiesting (16)	$200/pupil-year $343 - 400/pupil-year	Use by pupil during 10% of his time Total cost of instruction
1971	Miller (19)	$2 - $25/pupil-hour $5 - $100/pupil-hour	"Computerized Programmed Instruction" "On line computer aids to learning and scholarship"
1972	Dunn, Wastler (10)	$3.17/pupil-hour	Estimate for IBM 1500, 30 terminals Use: 9hr/day, 180 days/year, with 30 days in summer: 51,300 hr/year

* *This cost seems low.*

Year	Author	Cost	Comments
1972	CAI in New York City: Quoted in (2)	$3.73 / pupil - hour	RCA Spectra 70+192 terminals Expected cost: $3.17/pupil-hour
1970	Jamison, Suppes, Butler (33) - 1968 - 1969 - 1970 - 1971 (estimate)	$2,660 / terminal - year $2,230 / terminal - year	Average number pupils / day: 30 | 20 | 17.75 Cost per pupil per annum: $74 | $89 | $127
1972	Project PLATO, Bitzer (12, 4) PLATO III	$3 - $4 / pupil - hour	CDC 1604+75 terminals
	PLATO IV (estimate) *	$0.68 / pupil - hour $0.34 / pupil - hour	CDC 6400+1000 terminals CDC 6400 or 2 CDC 6500+4000 terminals
1972	Eastern Kentucky Educational Development Corporation (EKEDC) quoted in (12) Drill and practice, 7 to 10 min / day	$1612 / terminal - year	Feb. 1971 : RCA 70 / 45+26 terminals (ASR 33) End 1971, estimate : 64 terminals breakdown: computer $950 terminal $360 telephone $102 2 courses $200 (technical personnel to be added)

APPENDIX C

Suppes, Jamison and Butler (33) offer an estimate of the cost and efficiency of one of the largest systems of computerized instruction in operation at the present time. In 1970-71 in the city of New York, the system was based on an RCA Spectra 70 serving 192 terminals for *drill and practice*. The costs were as follows (in thousands of dollars):

	1968-1969 REAL COST Thousands of dollars	1970-1971 ESTIMATED COST Thousands of dollars
Hardware :	190	190
Courses :	20	20
Administration :	80	52
Personnel :	60	75
Telecommunications :	130	70
Teacher training :	15	13
Miscellaneous :	20	8
	575	428

Therefore, the overall cost for 1970-1971 was $2,230/year per terminal. If we estimate the use at 1600 hours per annum, the cost per pupil comes to $1.45/hr., which is exceptionally low.

However in June 1972, Elmer Bartels (2) quoted $3.73/hour per pupil for this system, while hoping to see this cost drop to $3.17 with a more intensive use of the system. Unfortunately, we have no information enabling us to explain this difference. Moreover, Bartels quotes this figure as one of the lowest available at the present time.

APPENDIX D

TABLE OF DTSS COSTS

(Dartmouth Time-Sharing System)

RATES 07 FEB 73 15:47

SCHEDULE OF RATES
AS OF NOVEMBER 1, 1972

I. RATES FOR USING THE DARTMOUTH TIME-SHARING SYSTEM

	INSIDE	OUTSIDE	COMMERCIAL
TERMINAL SERVICE			
10 CHAR/SEC	$ 1.40/HR	$ 2.15/HR	$ 5.25/HR
13.45 CHAR/SEC	1.55/HR	2.35/HR	5.80/HR
15 CHAR/SEC	1.65/HR	2.50/HR	6.15/HR
30 CHAR/SEC	2.30/HR	3.55/HR	8.65/HR
60 CHAR/SEC◇	3.25/HR	5.00/HR	12.25/HR
120 CHAR/SEC◇◇	4.60/HR	7.10/HR	17.25/HR
240 CHAR/SEC◇	5.55/HR	9.15/HR	22.40/HR
CPU/SEC	.04	.05	.15
STORAGE UNIT◇◇◇	.35	.55	2.00
I/O UNITS◇◇◇◇	.55	1.00	2.50
(COST IS PER 1000 I/O UNITS)			

◇ LIMITED AVAILABILITY; CONTACT KIEWIT COMPUTATION CENTER, HANOVER, N. H. 03755, PHONE (603) 646-2643 FOR MORE INFORMATION.

◇◇ NOT AVAILABLE AT PRESENT (10/31/72)

◇◇◇ A STORAGE UNIT CONSISTS OF 1000 WORDS (OR 4000 CHARACTERS). STORAGE CHARGES ARE BASED ON AVERAGE OF STORAGE FIGURES TAKEN WEEKLY.

◇◇◇◇ FOR AN EXPLANATION OF I/O UNITS, TYPE "EXPLAIN INOUT".

II. BACKGROUND RATES (FOR ON-CAMPUS USERS ONLY)

CARD READER	$ .01 PER 10 CARDS READ
CARD PUNCH	.01 PER CARD PUNCHED
HIGH SPEED PRINTER	.005 PER 10 LINES PRINTED
CPU USED	.04 PER SECOND
TAPE - READ	***** PER 1000 WORDS READ
TAPE - WRITE	***** PER 1000 WORDS WRITTEN

***** RATES TO BE DETERMINED JANUARY 1, 1973

III. RATES FOR USING GECOS

	INSIDE	OUTSIDE	COMMERCIAL
CPU USED/SEC.	$ .04	$ .06	$ .15

IV. FLAT RATE SERVICE AVAILABLE (FOR EDUCATIONAL USERS ONLY)

TYPE OF PLAN	DURATION	ACCESS	COST
PLAN A	9 MONTHS	FULL ACCESS	$ 550/MONTH
PLAN B	12 MONTHS	FULL ACCESS	$ 500/MONTH

NOTE: SPECIAL PERMISSION IS REQUIRED TO USE BACKGROUND AND GECOS. CONTACT MRS. NANCY BROADHEAD, KIEWIT, (603) 646-2643.

CPU IS AN ABBREVIATION FOR CENTRAL PROCESSING UNIT

READY

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